Experimental investigation of metal oxide nanofluid convection heat transfer

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Abstract

In this investigation convective heat transfer of two series of oxide nanofluids including $Al_2O_3/water$ and $CuO/water$ were studied experimentally. The flow was laminar and constant wall temperature was used as thermal boundary condition. The heat transfer coefficients for different concentration of Al_2O_3 and CuO nanoparticles at various Peclet numbers were experimentally determined. Also the viscosity of nanofluids was measured and compared with theoretical model predictions. Experimental results emphasize on the enhancement of heat transfer, which is due to the existence of the nanoparticles in the fluid. Heat transfer coefficient enhances by increasing the concentration of nanoparticles as well as Peclet number of nanofluid.

1. Introduction

Nanofluids represent a new class of engineering heat transfer fluids, which contain metallic or non metallic nanoparticles in base fluid [1] and offer exciting possibilities due to their enhanced heat transfer performance compared to conventional fluids. Nanofluids found to possess large effective thermal conductivity and also better stability compared to ordinary suspensions containing millimeter or micrometer sized particles [2, 3].

In this study laminar flow convective heat transfer of $CuO/water$ nanofluid under constant wall temperature at different volume fractions of nanoparticles was investigated experimentally.

2. Experiments

In the present study water based nanofluids of different oxide nanoparticles including Al_2O_3 and CuO with 20 *nm* and 50-60 *nm* diameters respectively in seven volume concentrations $(0.2\% - 3.0\%)$ were employed to measure the convective heat transfer in

circular tube with constant wall temperature. The experiments were conducted in laminar flow over a range of Reynolds number 600<Re<2000.

The dynamic viscosity of nanofluid was measured using cylindrical rheometer (Model HAAK RV12) at $24^{\circ}C$ and compared with theoretical correlation (Einstein model [4]). As shown in Figure (1) the values of viscosities versus shear rate are almost constant and confirm a Newtonian behavior for Al_2O_3 and CuO in volume fraction up to 3.0% of nanoparticles. According to Figure (1) $CuO/water$ nanofluid have higher viscosity in comparison with $Al_2O_3/water$ nanofluid at constant concentration conditions. This may result from the large particle size of CuO nanoparticles.

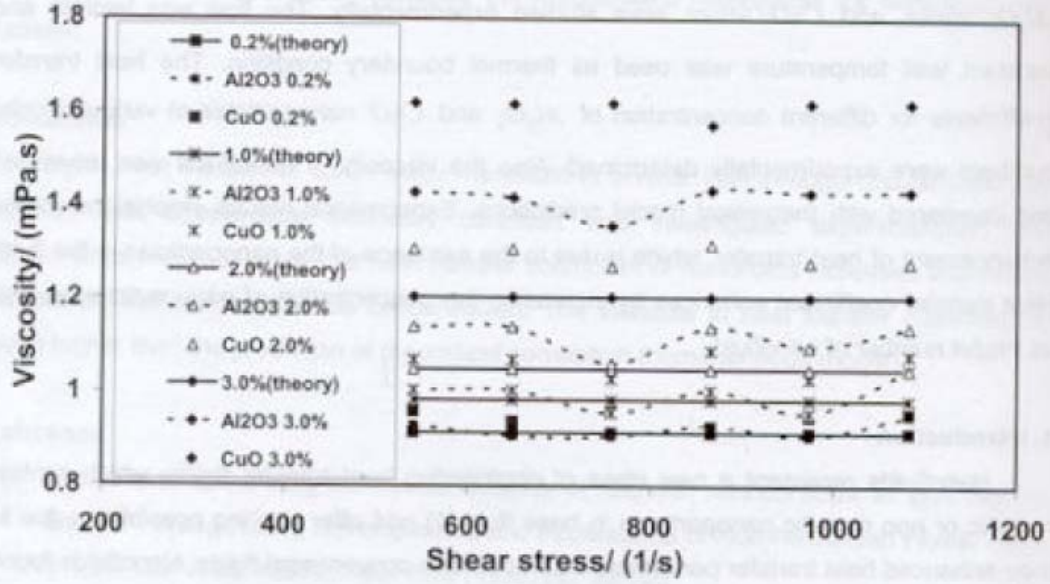

Fig. 1: Experimental and theoretical values of $Al_2O_3/water$ and $CuO/water$ nanofluids viscosity versus shear rate at different concentrations

Figure (2) shows experimental heat transfer coefficient of nanofluids versus Peclet number at different concentrations. In order to evaluate quantitatively the experimental heat transfer enhancement in comparison with Seider–Tate equation [5] prediction, the ratio of experimental Nusselt number to that of theoretical values for each nanofluid determined and presented in Figure (3) against Peclet number.

Figure (4) presents the experimental heat transfer coefficient ratio for each nanofluid to that of distilled water in various concentrations of nanoparticles versus Peclet number. The

results clearly show the enhancement of heat transfer coefficient for both nanofluids with nanoparticles concentrations as well as Peclet number, and the Al_2O_3 / *water* nanofluid *shows more enhancement in comparison with* CuO / *water nanofluid especially at high* nanoparticle concentrations.

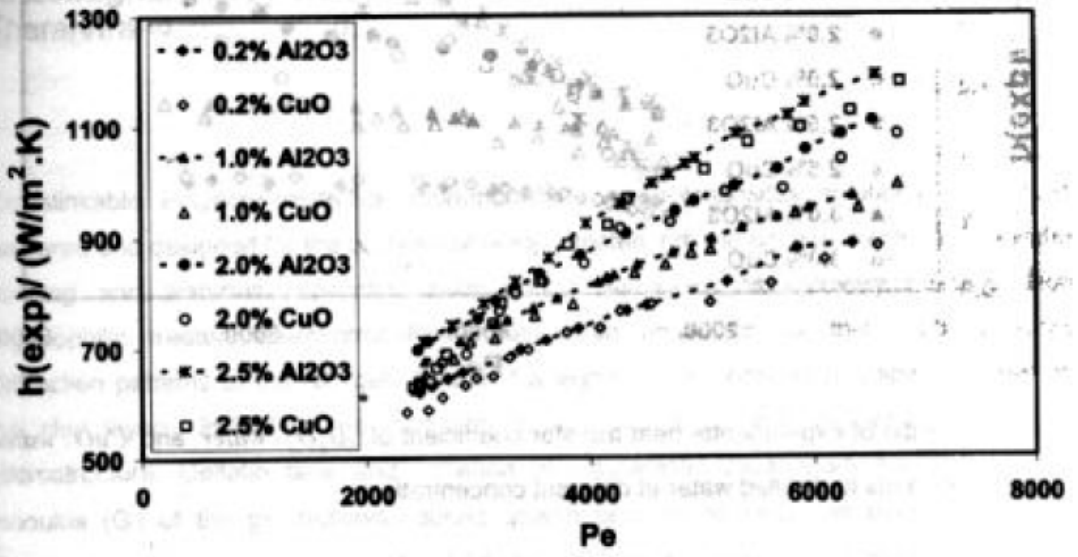

Fig. 2: Experimental heat transfer coefficients for Al_2O_3 / *water* and CuO / *water* nanofluids

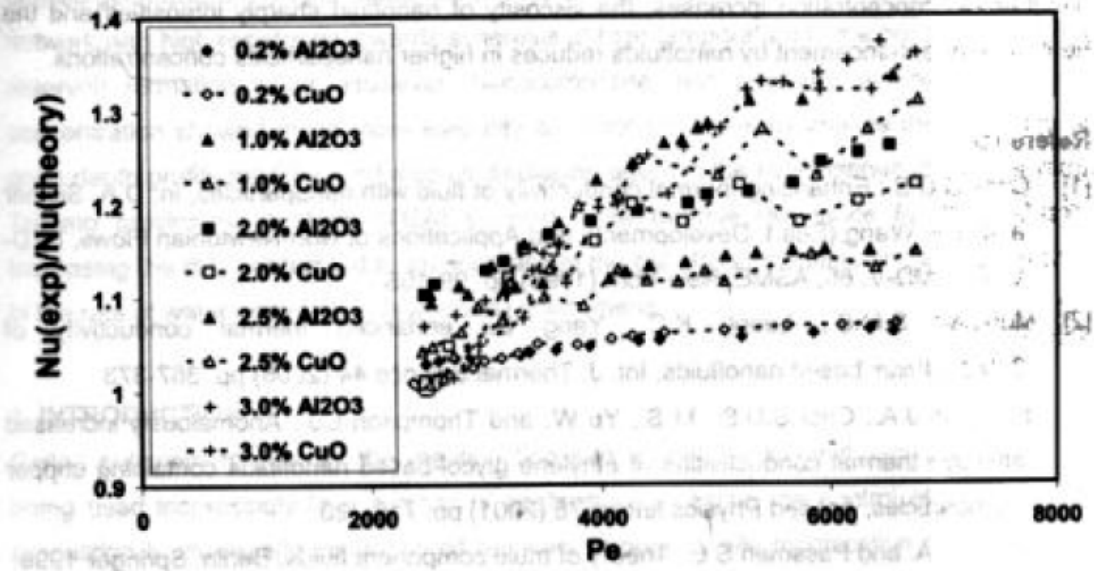

Fig. 3: The ratio of experimental Nusselt number to the Seider- Tate equation results for Al_2O_3 / *water* and CuO / *water* nanofluids

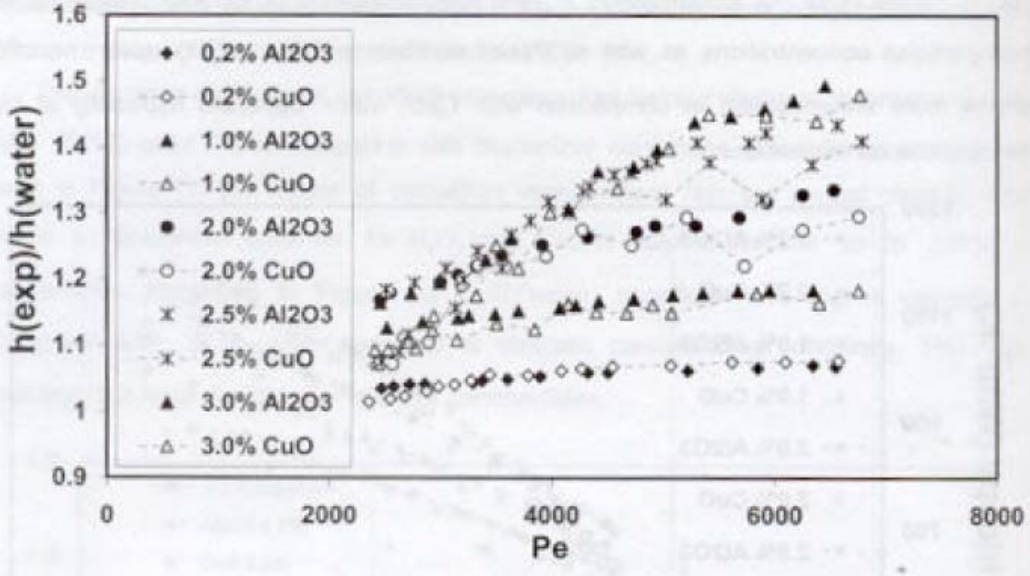

Fig. 4: The ratio of experimental heat transfer coefficient of $Al_2O_3 / water$ and $CuO / water$ nanofluids to distilled water at different concentrations

Results emphasize to existing an optimum concentration for all types of nanofluids in which better enhancement for heat transfer is available. It is due to the fact that as the nanoparticle concentration increases, the viscosity of nanofluid sharply intensifies and the heat transfer enhancement by nanofluids reduces in higher nanoparticles concentrations.

Reference

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